Modeling Strain Concentration Process in the Japanese Island Arc Crust Considering Heterogeneous Rheological Structure to Understand the Generation of Large Intraplate Earthquakes

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Recent large intra-plate earthquakes in Japan have occurred in strain concentration zones that have been revealed by the analysis of dense GNSS data. For example, the 2016 Kumamoto earthquake occurred in the strain concentration zone on Kyushu Island (Nishimura et al., 2016), and the 2016 central Tottori earthquake occurred in the Sanin strain concentration zone (Nishimura and Takada, 2017). It is thought that the strain concentration zones are caused by heterogeneous rheological structures, which result from the heterogeneous thermal structure, distribution of water content, and pre-existing rift structure. This study models various strain concentration zones in the Japanese Island arc crust in order to understand the generation processes of large intraplate earthquakes using a finite element method considering nonlinear viscoelasticity with the Mohr-coulomb criterion.

First, we model the Sanin strain concentration zone by considering the heterogeneous thermal structure. We set the boundary condition, which causes the strike-slip stress regime. Our model generates a strain concentration zone along the high geothermal gradient zone. Furthermore, small faults are generated in a direction almost perpendicular to the strike of the strain concentration zone. This model can explain the faulting process of the 2016 central Tottori earthquake, the strike of which was almost perpendicular to the strike of the Sanin strain concentration zone. We then develop a model of deformation and mountain building in the island-arc crust of central Japan. Central Japan is an area where several high mountain ranges have been formed by active crustal deformation. Dense geothermal observations indicate thermal anomalies in some areas. In this model, based on the J-SHIS deep subsurface structure (NIED), we consider a thick sedimentary layer where the friction coefficient is low. Numerical results show that under the compressional tectonic setting, the mountains are reproduced along a high geothermal region. In particular, we can reproduce the Hida mountain range, where a geothermal anomaly exists. Our model can thus reproduce mountains with consideration for the thermal structure, and the results are roughly consistent with the observations. However, the model cannot reproduce the strain concentration zone. Therefore, we consider the effect of water distribution in our model, and we discuss the effect of heterogeneous water contents in the crust for development of the strain concentration zone.